

# Age-Related Changes in the Auditory Reaction Time of Healthy Elderly Person while Walking

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**Abstract.** [Purpose] This study aimed to investigate the age-related changes in the attentional demand of walking in healthy elderly people by assessing auditory reaction time during walking in several age groups. [Subjects] The participants were 59 healthy elderly people with no history of falls in the previous 12 months, who were divided into 4 age groups (65–69, 70–74, 75–79, and 80–84). [Methods] In the dual-task condition, participants were asked to perform an auditory reaction time task while walking indoors; the Timed Up-and-Go Test, 10-meter walk time and Trail Making Test Part A were also measured. We compared the reaction times and the stride-to-stride time coefficients of variation between the single- and dual-task conditions. [Results] We found that mean reaction time and stride time coefficient of variation increased significantly in the dual task. However, in both task conditions, neither the reaction time nor stride-to-stride time coefficient of variation differed significantly among the age groups. [Conclusion] These findings indicate that an auditory reaction time task can affect walking as a second task in the healthy elderly, and that aging has minimal effects on the attentional demand of walking in this population.

**Key words:** Auditory reaction time, Gait, Elderly

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## INTRODUCTION

Walking has traditionally been considered an automatic movement with few attentional demands<sup>1)</sup>. However, recent research has cast doubt upon this view by investigating the relationship between gait and attentional demands using the dual-task paradigm, i.e., walking while another task is being performed simultaneously.

If gait were an automatic movement, a simultaneous task would not affect it<sup>2,3)</sup>. However, gait variables change in the dual-task condition, particularly in the elderly<sup>1,4)</sup>. Gait velocity decreases in the dual-task condition compared with the single-task condition, although the magnitude of this decrease depends on the type of participant and the second task<sup>4–15)</sup>. Elderly people with a history of falls (recent half or one year) and those with gait impairment, for example, those with Parkinson disease or hemiplegia, have more significant changes than healthy elderly people without a recent history of falls<sup>5,6)</sup>. Among healthy examinees, changes of gait velocity in the young and middle-aged are inconsistent, possibly a result of the task paradigm or the setting, but those of the elderly are nearly always significant<sup>4)</sup>. The coefficients of variation of gait variables increases in elderly fallers and those with gait impairment, but these changes are not consistent in elderly non-fallers

and young adults<sup>1,7,8)</sup>.

Few studies have investigated the age-related effects of the dual-task paradigm on walking in the elderly. Most studies of the attentional demands of walking have assessed only changes in gait variability; few have quantitatively assessed the performance of the second task because commonly used tasks, such as serial 7 subtractions and verbal fluency, are difficult to assess in this manner.

The auditory reaction time, measured using a simple digital voice recorder assessment system, has been used in recent studies as a second task to assess attentional demands because it can be quantified and standardized<sup>16–18)</sup>. Studies comparing the auditory reaction time during walking among the young, elderly non-fallers, and elderly fallers have found that the auditory reaction times of elderly fallers are significantly longer than those of other age groups<sup>16)</sup>. However, the age-related changes in auditory reaction time among the healthy elderly are unknown, as are the effects of auditory reaction time as a second task on walking in the elderly. Resolving these issues may help to clarify changes in the attentional demands of walking in elderly people. The purpose of this study was to determine in the healthy elderly: 1) the effect of the auditory reaction time task on walking and 2) changes in auditory reaction time during walking.

## SUBJECTS AND METHOD

The participants were 59 healthy elderly people. They were divided into 4 age groups (65–69, 70–74, 75–79, and 80–84) (Table 1). All participants were able to perform activities of daily living independently and had experienced no falls in the past year. All gave their written consent to participation in this study. The study procedures were approved by the Hirosaki University Ethics Committee.

We used 3 digital voice recorders (OlympusVN-6200, made in China). One was used as a stimulator, one as a recorder to measure auditory reaction time, and the other to record the sound of each heel contacting the ground. The stimulation set consisted of 16 vocal cues, with a preparatory signal presented before each. A random delay of 3–5 sec was set between the stimulation cues, and also of 2–3 sec between the preparatory signal and the stimulation cue. Cool Edit Pro 2.1 software was used to analyze the voice signals.

Reaction time (RT) was measured under both the single- and dual-task conditions. In the single-task condition, subjects were asked to respond to the stimulation cue of “de” from the digital voice recorder by uttering “pa” while sitting on a chair as quickly as possible. In the dual-task condition, subjects were asked to respond to the stimulation cue by uttering “pa” while walking at a self-selected velocity in a university gymnasium (21×17 m). All voices were recorded by another digital voice recorder located in the same place as the stimulation device. Before the test participants were asked to practice one set (16 vocal cues) in order to familiarize themselves with the procedure. For both the single- and dual-task conditions, only one set of RT measurements was made. The sounds of each heel contacting the ground were recorded simultaneously and converted into stride-to-stride time and then into coefficient of variation of stride-to-stride time (WCV\_dual). The stride-to-stride time coefficient of variation during free walking (WCV\_single) was also assessed by the same method. Twenty continuous walking periods were used for analysis. In the dual-task condition, the walking periods contained about 3 RT measured periods.

Each subject also performed the Timed Up-and-Go Test (TUG), 10-meter walk time (10MW) (to assess movement function), and Trail Making Test Part A (TMTA). The TUG and 10MW were measured twice and the better performance

**Table 1.** Characteristics of subjects

Age group	N (female)	Height (cm)	Weight (kg)
65–69 y	13 (9)	157.1 ± 6.7	56.5 ± 1.0
70–74 y	21(14)	154.8 ± 7.8	56.1 ± 7.8
75–79 y	18 (10)	154.2 ± 6.5	56.4 ± 7.2
80–84 y	7 (4)	152.7 ± 1.0	58.6 ± 9.7

was used in the analysis; TMTA was measured only once to avoid learning effects. The tests were performed in a random order.

One-way ANOVA was used to compare 10 MW, TUG, WCV\_single, WCV\_dual, TMTA, RT in the single task condition (RT\_single), and RT in dual task condition (RT\_dual) among age groups, and Fisher’s PLSD was used for multiple comparisons. To quantify relationships with age, correlations between each variable were analyzed using Pearson product-moment correlation coefficients. The paired-t test was used to compare items between single task and dual task. Reported p-values reported are based on two-sided comparisons, and p-values of 0.05 or lower were considered to indicate statistical significance. All statistical analyses were performed using SPSS16.0.

## RESULTS

Table 2 summarizes test performance results. TMTA differed significantly among the age groups and increased with age ( $F_{3,58} = 3.15$ ,  $p = 0.032$ ;  $r = 0.436$ ,  $p = 0.003$ ). The 70–74y age group differed significantly from the 80–85y age group ( $p < 0.01$ ). RT\_single did not differ significantly among the age groups and showed no tendency to increase with age ( $F_{3,58} = 0.334$ ,  $p = 0.801$ ;  $r = 0.071$ ,  $p = 0.592$ ).

Both 10MW and TUG differed significantly among the age groups (10MW  $F_{3,58} = 4.145$ ,  $p = 0.012$ ; TUG  $F_{3,8} = 5.515$ ,  $p = 0.003$ ). The 10MW results for the 65–69y group differed significantly from other age groups with the exception of the 70–74y group, and they were also significantly different between the 70–74y and 80–84y groups. The TUG results for the 80–84y group significantly differed from the other three groups, and they were also significantly different between the 65–69y and 75–79y group. The 10MW increased with aging ( $r = 0.44$ ,  $p < 0.001$ ) and TUG showed similar results ( $r = 0.519$ ,  $p < 0.001$ ).

**Table 2.** Summary of the test results

	TMTA (s)	10MW (s)	TUG (s)	RT_single (ms)	WCV_single (%)	RT_dual (ms)	WCV_dual (%)
65–69 y	99.6 ± 3.7	5.33 ± 0.58	6.52 ± 0.74	251 ± 47	1.68 ± 0.39	288 ± 57	2.23 ± 0.65
70–74 y	93.0 ± 2.3	5.83 ± 0.56	7.17 ± 0.88	240 ± 57	2.01 ± 0.72	290 ± 79	2.53 ± 0.92
75–79 y	122.4 ± 4.1	5.97 ± 0.52	7.66 ± 0.89	259 ± 67	1.62 ± 0.69	290 ± 73	2.12 ± 0.91
80–84 y	117.6 ± 2.0*	6.61 ± 1.39*	8.73 ± 2.15**	249 ± 51	2.39 ± 1.50	290 ± 50	2.34 ± 1.28
r (age)	0.436**	0.472**	0.391**	0.037	0.077	0.045	–0.013

r (age): correlation with age; \*  $p < 0.05$ ; \*\*  $p < 0.01$ .

**Table 3.** Performance under single- and dual-task conditions

Item (n=59)	Single-	Dual-
RT (ms)	249 ± 57	290 ± 68**
WCV (%)	1.863 ± 0.806	2.316 ± 0.908**

\*\*p&lt;0.01

WCV\_single did not differ significantly among the groups ( $F_{3,58}=2.158$ ,  $p=0.103$ ) and showed no tendency to increase with age ( $r=0.125$ ,  $p=0.346$ ).

In the dual-task condition, there were no significant inter-group differences in RT\_dual or WCV\_dual; these variables showed no tendency to increase or decrease with age. We therefore normalized RT\_dual as a percentage of RT\_single ( $RT\_dual/RT\_single \times 100\%$ ). However, normalized RT also showed no significant differences among the age groups.

We compared items between the single-task and dual-task conditions (Table 3). Both RT and WCV increased significantly in the dual-task condition compared with the single-task condition ( $p<0.001$ ).

## DISCUSSION

We found that RT was prolonged and WCV increased in the dual-task condition compared with the single-task condition. These results suggest that auditory reaction time and walking interfere with each other.

Previous studies using the dual-task paradigm have found WCV to be strongly correlated to fall risk<sup>7,8</sup>. These studies showed that WCV was higher in the dual-task condition than in the single-task condition in elderly fallers. However, the same pattern was not consistently found in healthy elderly non-fallers. For example, Yogev et al. used an arithmetic task as a second task and compared the WCV between the single-task condition and dual-task condition in patients with Parkinson's disease and healthy elderly people<sup>7</sup>. They found a significant difference in WCV in the Parkinson patient group, but no significant difference in the healthy elderly. In contrast, Dubost et al. used verbal fluency as the second task and found a significant difference in WCV between the single-task and dual-task conditions in the healthy elderly<sup>8</sup>. The present findings support those of Dubost et al.

The reasons for these discrepancies in results may include the type of second task and the experiment environment<sup>1</sup>. Researchers have determined certain criteria for the second task of a dual-task paradigm<sup>1</sup>. First, the second task should be an attentional demand task having enough difficulty to interfere with the main task. According to the theory behind the dual task, individuals have an attention capacity, and walking cannot be interfered with by the second task performed simultaneously if that task is not difficult enough. Hence the auditory stimulation reaction time used in the present experiment can be considered to have had adequate difficulty. Additionally, performance of the second task used in a dual-task paradigm should be

influenced by the subject's cognitive ability as little as possible<sup>1,6</sup>. For example, with an arithmetic task there are large individual differences in calculation ability. Some people will be able to perform well in the primary task because they have greater mathematical skills, while others may perform worse because they have not developed such skills. The same considerations apply to verbal fluency tasks. With the present auditory reaction time task, the stimulation sound was simple, allowing subjects to detect it easily, even if they had some hearing loss. They were required to answer the stimulation sound in monosyllabic responses only. Hence the test was simple to respond to and individual differences in the auditory stimulation reaction time task were small.

No significant difference was observed in RT\_dual among the age groups in this study. In other words, aging had a minimal influence on RT\_dual in these healthy elderly participants. As a measure of dual-task performance, RT\_dual is determined by 2 factors: physiological condition and RT\_single. With increasing age, changes occur in cerebral structure, particularly in the prefrontal area, which is related to executive function and attention function.

According to these structural changes, cognitive function tends to decline with age<sup>20</sup>. However, the degree of decline in cognitive function in the elderly is unknown. The TMTA, which is a measure of attention ability, differed significantly among the age groups but had a weak correlation with age. Further, RT\_single was not correlated with age. These data indicate that attention is poorly correlated with age in the elderly. This is consistent with the view of Lezak, who considered that although attention ability tended to decline with age, this decline is not marked<sup>21</sup>.

Walking velocity, an important parameter of walking function, differed significantly among the age groups in the present study, suggesting that walking function declines with aging in the healthy elderly. However, the values were within the normal range reported by previous studies. Moreover, WCV\_single showed neither significant inter-group differences nor a significant correlation with age. As described in the Introduction, walking is an attentional demand movement and requires greater attention in people with impaired gait. However, if walking ability is not markedly impaired, the parameters of WCV\_single and RT\_single may not change significantly.

The present findings that neither RT\_dual nor RT\_single differed significantly among the age groups suggests that aging has no apparent influence on the attentional demand of walking in the healthy elderly.

This study had some limitations. First, we excluded subjects with a recent history of falls and those with gait disorder in this study. In the future, we plan to measure the RT of such patient groups in order to investigate clinical applications. Second, this study was a horizontal study, and a longitudinal study is necessary to determine any changes in attentional demand of walking among individuals with age. Lastly, the number of subjects in each group was small, far fewer than the 28 people in each group that we planned, particularly in the 80+ age group.

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